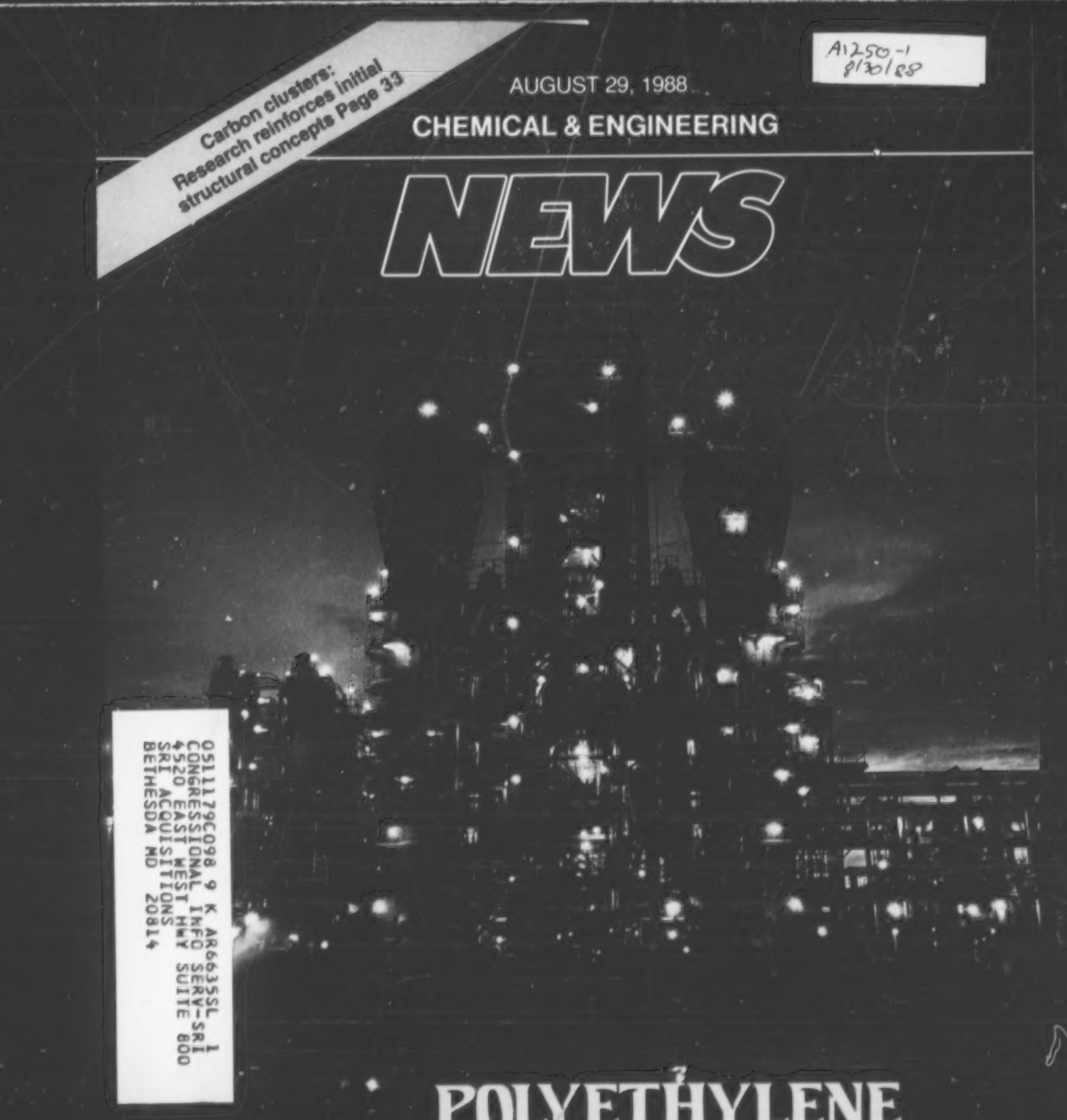
A1250-1
8/30/88

AUGUST 29, 1988

CHEMICAL & ENGINEERING

NEWS

Carbon clusters: Research reinforces initial structural concepts Page 33



0511179C098 9 K AR6635SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

POLYETHYLENE

Output limited by tight ethylene supplies Page 12

CHEMICAL & ENGINEERING
NEWS
Volume 66, Number 35
CENEAR 66 (35) 1–60
ISSN 0009-2347
AUGUST 29, 1988

News of the Week

■ **The space shuttle *Discovery* has passed its final two big tests, is set to lift off in about a month.** **Page 4**

■ **Group of scientific societies has written the Presidential candidates with its views on science and technology policy.** **Page 5**

■ **Steps are being taken that could lead to a national system that would provide a computer network to support research.** **Page 5**

■ **Gambling that the University of Houston will be granted patents on high-temperature superconductors, Du Pont has purchased the rights to commercialize them.** **Page 6**

■ **In a move to further bolster its major position in paints and coatings, PPG Industries plans to acquire New York City-based Grow Group.** **Page 6**

Cover: Union Carbide's Star polyethylene plant at Taft, La.

Letters 2
Editor's Page 3

Concentrates
Business 7
Government 18
Science/Technology 28

The Departments
ACS Focus 40
ACS News 41
People 41
Meetings 43
Newscripts 60

Business

Major changes are taking place in the global pharmaceutical industry, study by British consultant shows. **Page 16**

Government

With work completed on the massive trade bill, Congress is busying itself with a raft of other issues. **Page 22**

Republican platform addresses in detail the party's position on science and technology matters. **Page 24**

EPA rule restricts land disposal of large portion of hazardous wastes, adding considerably to their disposal cost. **Page 26**

Science

Research indicates that 60-carbon buckminsterfullerene species has a spherical structure, is more prevalent than previously thought. **Page 33**

Technology

New strain of bacteria developed at the Institute of Gas Technology selectively removes organic sulfur from coal. **Page 36**

Corrosion problems of construction materials are focus of expert system project at materials institute. **Page 38**

Priestley exhibit of the Beckman Center for the History of Chemistry has been moved to the Joseph Priestley House in Pennsylvania. **Page 38**

A Soviet reconnaissance satellite that is currently losing altitude may hit Earth this fall along with its nuclear-fueled power supply. **Page 39**

Cover Story

Tightening ethylene supplies together with rising demand for polyethylene and other ethylene derivatives have led to higher polyethylene prices and above-optimum plant operating rates. **Page 12**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin

Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski

Staff Editor: Ernest L. Carpenter

Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer

Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer

Service Departments Editor: Dolores Miner

Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)

Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos

Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K. Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*), *Board of Directors Chairman*; Ernest L. Eliel, *President*; Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jeanne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988: Printed editions, nonmembers U.S. 1 yr $49, 2 yr $83, outside U.S. 1 yr $75, 2 yr $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 59)

LETTERS

Membrane technology

SIR: In response to the article by Joseph Haggin, "New Generation of Membranes Developed for Industrial Separations" (C&EN, June 6, page 7), a little fish in the big sea seems to have been overlooked. Please note that A/G Technology Corp. has introduced a series of gas separation membranes for nitrogen enrichment and oxygen enrichment. Some of our industrial customers actually believe A/G Technology is at the cutting edge of hollow-fiber membrane technology. Two recently issued patents suggest we will continue to be a player in this highly competitive field.

Although we are proud of our accomplishments to date and the bright future ahead, we must sadly admit we are not a Fortune 100 company—yet!

Steven J. Polen
A/G Technology Corp.
Needham, Mass.

Abolishing unemployment

SIR: We hear a great deal these days about human rights. We berate our friends and adversaries and at the same time we ignore one of the basic human rights: the right to work.

I heard an interview on one of the networks in which a Vietnam veteran complained that he was unemployed for three years, has a wife and three children, has exhausted all his benefits, and now has only one chance—and that is crime.

Some time ago I saw a letter in C&EN in which a poor Ph.D. chemist complained that he was dismissed after 23 years of service because business was poor. I will never forget his last sentence: "To be unemployed means to die." The medical literature tells us that unemployment will cause not only mental and psychological disturbances but also actual physical illness.

Unemployment creates resentments towards society. The hostility is cumulative and drives people to acts that they would never commit while employed. It is a sad fact that the majority of crimes are committed by the unemployed. The majority of drug addicts are unemployed. It is well known that it costs more to keep a person unemployed than to keep him or her in regular employment. It costs more—much more—to send someone to jail than to Harvard.

Building prisons will not solve the problem. There is so much work to do in our country: eliminate the slums; build adequate and decent housing; beautify the towns and the countryside; repair our dilapidated roads, bridges, and dams; prepare our youth and unemployed for useful occupations, and so on.

We have the materials, the know-how, and the work force. So why don't we abolish unemployment? It will solve many of our most serious problems. And then, only then, could we preach about human rights.

Andrew A. Recsei
Santa Barbara, Calif.

Particle accelerators in space

SIR: We have read with great interest the letter by Robert Pellenbarg on a lunar supercollider (C&EN, May 30, page 3). We have been working for more than a year on the conceptual design of particle accelerators in high Earth orbit (PAHEO). In the phrase "high Earth orbit," we include as a special case, lunar siting. We would like to point out some results of our analysis that are germane to Pellenbarg's letter.

We do concur with the idea that the space environment offers important advantages when designing a PAHEO. Pellenbarg mentions high vacuum, cryogenic temperatures (suitable for high T_c superconductors), promotion of the peaceful use of space, and focusing the space program on a noteworthy goal.

We note that there are several additional advantages; for example, a PAHEO can be enlarged through modular design and can utilize comparatively inexpensive solar power. Fully and aggressively exploiting conditions in space can yield design simplifications with concomitant cost reductions compared with comparable Earth-based facilities for accelerators operating at energies greater than or on the order of 100 TeV.

The time scale that we consider meaningful for implementation of a PAHEO is of the order of 25 years, which places the operation of a PAHEO in the early 21st century. The main consideration is the development of the necessary infrastructure in near-Earth space. This guesstimate coincides with the one obtained from the lunar-Antarctica analogy mentioned by Pellenbarg, since half a century elapsed between the arrival of Amundsen and Scott at the South Pole and the International Geophysical Year

Continued on page 43

Polyethylene, Other Derivatives Feel Worsening Ethylene Crunch

Tight ethylene supply coupled with increasing demand for derivatives of monomer are pushing plant capacity use rates above optimum levels

Bruce F. Greek, C&EN Houston

The supply crunch for ethylene and its derivatives is worsening. Rising demand is pushing capacity use for polyethylene and other ethylene derivatives above optimum levels. However, production of ethylene derivatives this year will depend more on availability of ethylene than on demand or capacity for these derivatives. Polyethylene prices have almost doubled in a year's time, but high prices are doing little yet to dampen vigorous demand growth.

Relief from the current supply and demand crunch for ethylene, polyethylene, and other ethylene derivatives is not expected until the early 1990s. When recently announced large steam crackers go on stream in three years, ethylene consumers will have less difficulty getting ample feedstock.

Because polyethylene capacity use is limited by ethylene supply, this year's polyethylene production will be about 18.6 billion lb, a modest growth of 5 to 6% over 1987 production. Growth of 9.3% last year over 1986 output was the highest growth since 1983, when more than a 10% gain was recorded. The outlook for 1989 is for a smaller gain, because the limits on ethylene supply are expected to continue.

Although monomer supplies are tight, polyethylene capacity continues to grow this year. Several expansions have come on stream or will be coming on stream in 1988. Westlake Polymers plans to restart a 400 million lb-per-year low-density polyethylene unit near Lake Charles, La., that has been shut down since Cities Service exited the business several years ago. Earlier this year, El Paso Products restarted an idled 125 million lb-per-year plant to make LDPE at Bayport, Tex. Capacity of Quantum Chemical's Port Arthur, Tex., plant for LDPE has been increased 300 million lb. In the Baton Rouge, La., area, 95 million lb of high-density polyethylene capacity by Allied-Signal and 70 million lb of LDPE capacity by Exxon Chemical will be added by the end of the year. Phillips 66 will bring on stream an additional 105 million lb of HDPE capacity at Pasadena, Tex., by year's end. Other small debottlenecking activities are likely and will add another 200 million lb-plus to the several types of polyethylene capacity.

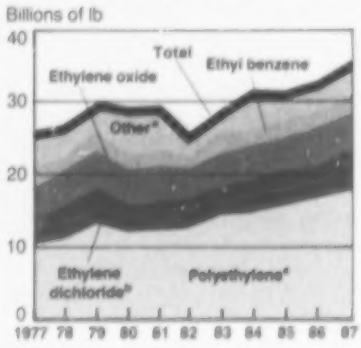
From 1989 to 1991, as much as 5 billion lb of capacity for polyethylene will be added. Current producers all will be represented in those expansions or in expansions occurring in 1988. By the end of 1991, U.S. capacity to make polyethylene will exceed 23.5 billion lb.

Operating rates for polyethylene plants, nevertheless, will remain above 90% of nameplate capacity until at least 1990, says Clark E. Bird, marketing manager for Novacor Chemicals, a major producer of linear low-density polyethylene in Canada. If the announced capacity expansions all are completed on schedule and if sufficient ethylene also somehow becomes available for production levels to meet expected demand, then the average operating rate may decline in 1991 to the mid-80% range. Operating rates likely will again climb later on in the 1990s, Bird says, because demand will grow in both well-established and developing markets.

Global capacity to make polyethylene also is rising. At the end of 1988, world capacity outside the East bloc will be 24.5 billion to 25.0 bil-

Ethylene shortage has delayed HDPE capture of half-gallon milk bottle market

Polyethylene takes growing share of ethylene output



a Includes alpha-olefins, linear alcohols, ethanol, vinyl acetate, ethylene-propylene rubbers, other chemicals, losses, and inventory changes. b About 80% used to make polyvinyl chloride. c Includes copolymers.
Source: C&EN estimates based on data from Society of the Plastics Industry's Committee on Resin Statistics and from U.S. International Trade Commission

lion lb, up from about 22.8 billion lb at the end of 1987, according to John S. Doerr, president of International PC, a consulting firm in Houston. Based on announcements of planned expansions, Doerr forecasts that during the next two years, 6.8 billion lb of capacity will be added outside the East bloc. He says, however, that capacity additions frequently run above initially announced quantities, resulting in revisions to nameplate capacities.

If the large additions to global capacity are completed according to schedule, an overcapacity for making polyethylene could develop. Capacity could rise faster than demand, if demand growth follows historical patterns. Serious overcapacity is unlikely, however, says Earl H. Simpson, manager of chemical analysis at Bonner & Moore Market Consultants in Houston, because demand for polyethylene and other plastics is growing so rapidly in developing countries. As long as polyethylene resins are available, Simpson says, consumption would be more likely limited by the availability of conversion equipment to fabricate products of polyethylene. In China, use of polyethylene is currently at about the per capita level that it was in the U.S. 30 years ago, illustrating the ease with which large capacity expansions under construction in China and large imports of polyethylene will be consumed through demand growth in developing countries.

Large polyethylene capacity expansions outside the U.S. apparently will not dampen U.S. exports, especially of HDPE resins. Imports of LDPE resins in 1987, predominantly from Canada, exceeded exports for the first time in recent history. U.S. exports of LDPE declined in 1987 by more than 150 million lb, to about 700 million lb. Capacity in Canada is now operating fully, so imports from Canada are not expected to rise much during the next two years.

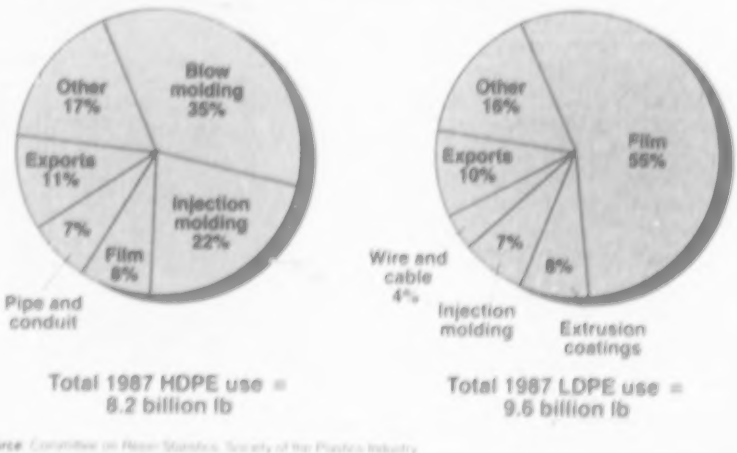
Exports of LDPE, particularly of linear low-density polyethylene, may decline because a large number of LLDPE plants are being built outside the U.S. Another factor affecting exports is that U.S. demand for polyethylene is rising faster than production because of constraints on ethylene availability.

Although prices have climbed from less than 30 cents a lb for grades sold in large volume to more than 50 cents a lb, polyethylene demand in the U.S. and worldwide is still growing strongly. Prices are expected to increase as long as supply remains tight, although producers are attempting to hold down prices lest consumers shift to other materials. Margins for polyethylene producers have risen substantially because price increases have averaged more than 2 cents per lb per month over the past year, even though ethylene prices have more than doubled during this period. Polymer producers may be trying to absorb some of the cost increase in ethylene but are expected to pass on at least part of future increases.

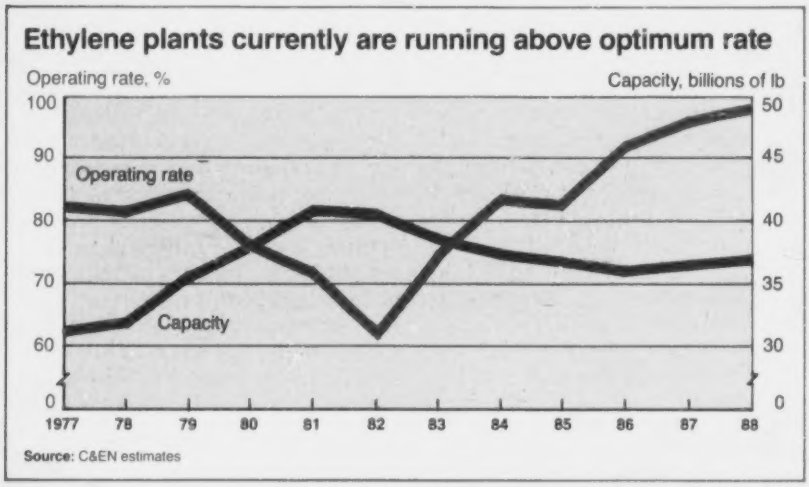
Consumers of polyethylene resins are resisting polymer producers' price increases, according to industry sources. But polymer producers find there is little movement to replace polyethylene in uses that have been captured since these plastics became widely available in the 1950s. The ultimate consumers apparently are willing to accept substantial increases in product costs for the performance of items fabricated from polyethylene. For example, people are not likely to give up HDPE 1-gal milk containers—unless 25 cents or more were added to the total cost. Nor would the many fabricated film uses, such as bread wrappers, be replaced unless substantial amounts were added to the cost of bread.

More likely, capture of new markets will be slower than anticipated, says William C. Kuhlke, a vice president with the Houston-based consulting firm, DeWitt & Co. Kuhlke cites as examples a slower growth in use of HDPE to make storage drums and fuel tanks for trucks and cars, both uses once forecast to grow rapidly because of the potentially lower fabrication costs and corrosion resistance of the polymer. Both long-term supply and anticipated future resin cost weigh heavily in decisions made to change to poly-

Polyethylene use breaks down this way



Source: Committee on Resin Statistics, Society of the Plastics Industry



ethylene for uses in which a semi-permanent commitment will be required.

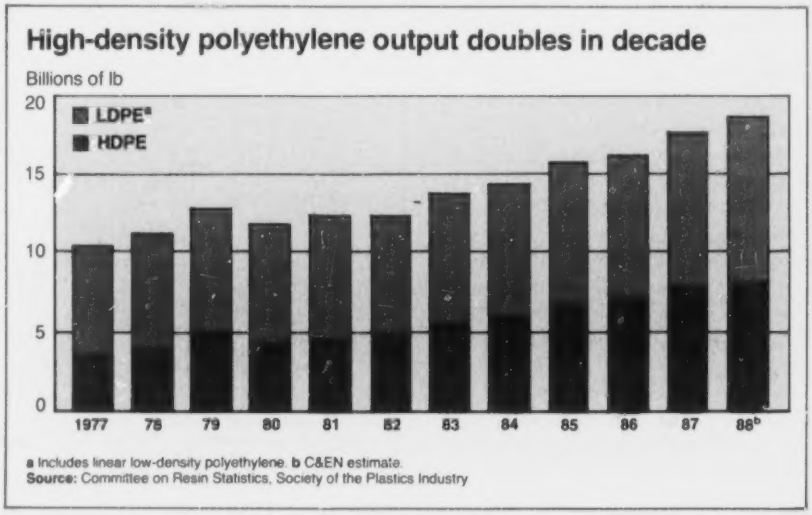
Tightness in polyethylene supply, for at least the next 18 months, will keep present use patterns intact, according to industry sources. The tightness also will limit development of uses within the major market segments. For example, further penetration of HDPE blow-molded milk bottles into the half-gallon size now seems to be in limbo, pending additional supplies of polyethylene suitable for this use. Hence, blow molding uses of HDPE are unlikely to expand their share of consumption. Film uses of both LDPE and LLDPE also are expected to hold their share (about 55%) of total use. Film uses of HDPE, including various kinds of blends with LDPE and LLDPE, have been growing rapidly because of penetration into the grocery and other retail store bag markets. However, supply limits and competition from other uses for HDPE that fetch higher prices could slow growth in film uses. Exports of polyethylene may sag as polymer producers find U.S. consumers more willing to pay higher prices to meet expanding demand for fabricated items.

If growth in polyethylene were not limited by tight ethylene supply, the pattern formed in the early 1980s of HDPE output growing faster than that of LDPE would change. That change would occur because, recently, LDPE growth has improved through the development and rapid acceptance of LLDPE. Both LLDPE capacity and production were forecast to rise at more than 10% annually until the monomer supply crunch hit. Much of the big growth in consumption of LLDPE has been in film, which now accounts for nearly half of the total use. The largest film use is for making trash bags, in which LLDPE provides greater strength than LDPE, thereby permitting thinner films to be used and thus lowering costs. Frequently, blends of LLDPE and LDPE are used in film for cost and performance reasons. The trash bag market has been almost completely captured by LLDPE alone or in blends. However, forecasts of growth in this use of 4 to 6% annually have been revised downward because of the supply and demand crunch.

Most of LLDPE's other film uses, which account for about half, are commercial and industrial packaging, retail store bags, and food packaging. Of these, most are still limited to packaging where very high clarity is not important. Efforts to move LLDPE into markets where clarity is important have lessened, now that meeting total demand takes priority over gaining new markets. LDPE and ethylene-vinyl acetate copolymers blended with LLDPE account for the remainder of the film uses.

Future growth in LDPE use will stem largely from increased demand for LLDPE, which accounts for most of the expansion in capacity. Many of the conventional LDPE plants are old and many have been debottlenecked as much as is economically practical. Thus, capacity growth for these units could amount to less than 1% annually. Some LLDPE capacity can be used to make HDPE, with estimates of this "swing" capacity clustered around 850 million lb of HDPE this year. Much of the new HDPE capacity under construction will be able to make LLDPE, depending on demand for the polymer. Possibly 1 billion lb of capacity additions over the next three years will be used to make HDPE.

The major uses of HDPE remain in blow- and injection-molded items. Bottles for milk, juices, and household products dominate the blow-molded products. A few years ago, HDPE captured most of the 1-gal milk bottle market. A year ago, the resin seemed poised to capture the half-gallon market, but limited res-



in supply now has delayed major inroads in this market for two years, according to industry sources.

Shipping pails with separate lids; various kinds of crates, trays, and cases; housewares; and food containers account for most of the HDPE fabricated by injection molding. HDPE encounters competition from polypropylene in several of these applications. Growth in injection-molded HDPE uses will about keep pace with blow-molding uses, except for a temporary dip as tight resin supply likely will allow polypropylene to gain a larger share.

Film uses of HDPE have been growing nearly twice as fast as those for all HDPE uses, but from a smaller base. Bags used in retail stores account for 40 to 50% of this market for HDPE. Most of the film is a blend with other types of polyethylene to capitalize on strength characteristics and thinner film. Until HDPE supply eases, growth rates for film uses are expected to stay below the recent rate of 20% per year.

With output of polyethylene and other ethylene derivatives constrained by ethylene supply, derivative producers, including captive producers, are closely monitoring the outlook for ethylene production. This year, some swings in ethylene output because of plant problems have compounded the supply difficulties. During the second quarter of 1988, Shell Chemical and Texaco Chemical had units with total nameplate capacity of more than 3.4 billion lb go down. Two Shell units at Norco, La., have returned to operation, although they are not yet at full capacity. Texaco also has restarted its Port Arthur, Tex., unit and it has reached capacity. Slightly more than 400 million lb of ethylene apparently were not produced in the second quarter because of these and other interruptions of plant operations, according to data compiled by Ernst & Whinney for the National Petroleum Refiners Association. Inventories of ethylene also were drawn down by about 170 million lb during the second quarter.

As a result of startup of the Shell and Texaco units and minimal scheduled maintenance shutdowns, third-quarter ethylene production likely will about equal the first quarter's 9.2 billion lb. If no other major plant problems develop for the rest of the year, production of ethylene this year could come close to 36.5 billion lb. To reach that level of production, existing capacity will have to be run at about 98% of the nameplate total for units actually in operation for at least part of the year.

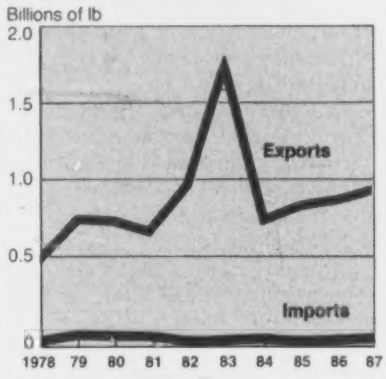
In 1989, Texaco will restart a unit with a capacity of about 350 million lb per year at Port Neches, Tex., and Union Carbide will restart a 450 million lb unit at Taft, La. These units, others that possibly will be restarted, debottlenecking, high use of ethane as one feedstock to steam crackers, and more recovery of ethylene from refinery streams from catalytic cracking could allow an additional output of 1 billion lb of ethylene.

As this additional ethylene becomes available, much of it will be used in derivative units to make ethylene oxide, ethylene dichloride, ethyl benzene, and other chemicals, as well as polyethylene. Earlier this year, production of derivatives other than polyethylene was held down because ethylene was preferentially used in polymers producing higher margins, says Hugh S. Pylant, a senior consultant at Pace Consultants in Houston. However, substantial price increases for other ethylene derivatives, such as 10 cents per lb on July 1 for ethylene oxide to bring its price to 50 cents per lb, have improved margins for those derivatives to about the level of polyethylene, Pylant says.

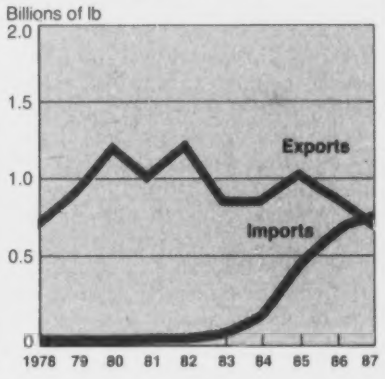
With margins for ethylene and its derivatives now at levels that permit reinvestment, producers are trying to hold the line on further price increases. Currently the price of ethylene is about 31 cents per lb, the same as in July, and is expected to hold. Until this month, ethylene prices had been rising 1 to 2 cents each month in 1988. Prices for ethylene over the past five years bottomed out about a year ago, at around 13.5 cents per lb.

The rises in ethylene prices designed to bring margins to reinvestment levels have touched off plans for a new round of steam crackers to make ethylene. So far in 1988, decisions to build world-scale units have been made by Dow Chemical, Quantum Chemical, and Phillips Petroleum for a total of 4.5 billion lb. Another 6 billion lb of capacity made up of 0.8 billion lb of restarted old capacity and 5.2 billion lb of other new capacity will be added in the U.S. by 1993, according to William L. Urquhart, manager of chemical planning at Bonner & Moore, who recently has completed a new study on the outlook for ethylene. This 10.5 billion lb of capacity would be a 29% jump over mid-1988 capacity, Urquhart adds, and it suggests a temporary overcapacity. An economic recession, reducing ethylene demand at the same time as new capacity starts up, could send prices down, he says. □

HDPE has maintained a positive trade balance . . .



. . . but LDPE recently has run a trade deficit



Source: Department of Commerce

Global pharmaceutical industry undergoing major shifts

Patricia L. Layman, C&EN London

The world pharmaceutical industry, by some estimates, is worth $100 billion a year. It is increasingly mature, at least in developed countries, and that maturity is affecting many facets of the industry in ways ranging from research and development to relationships with governments where companies are located. And the balance of power in the industry is slowly but surely shifting from the established power bases to new ones, in the face of massively increasing amounts needed to stay in the business.

Those are some of the conclusions of Heinz Redwood, a pharmaceutical industry consultant based in Felixstowe, England, who recently completed a new study, "The Pharmaceutical Industry: Trends, Problems, and Achievements," looking at the industry around the world.

Research and development is the major area of the industry to reflect the escalating costs associated with it. From what Redwood reckons as roughly $500 million spent worldwide on pharmaceutical R&D in 1964, spending reached $7.2 billion by 1983, and probably will be more than $10 billion this year.

In 1964, the U.S. was the biggest spending region, but by 1973, it had been overtaken by Western Europe—$1.01 billion, compared with the $753 million spent by the U.S. pharmaceutical industry. European industry has kept its lead ever since. On a country-by-country basis, however, by 1983 Japan had emerged as the second highest spender, with its industry spending $964 million on R&D, more than the $916 million spent by the pharmaceutical industry in West Germany.

According to Redwood, in the decade to 1983, the long-term trend of a falling U.S. share of pharmaceutical R&D spending worldwide continued. However, despite the increases by Japanese industry, the U.K. had the greatest gain in world share of R&D spending, from 5% in 1973 to 10% in 1983. This he attributes to a series of successful international launches of commercially important compounds from British research, from about 1970 onward, which inspired confidence in further funding.

On the other hand, West German efforts fell off a bit. And Swiss pharmaceutical companies have not been able to match their record from the several decades immediately following World War II.

Redwood analyzed in detail two time spans, 1961–77 and 1981–85. According to industry statistics, U.S. companies were the most innovative in both time spans, but their share of all new drugs introduced around the world increased only from 24% to 25%. Japan, however, undoubtedly benefiting from the increased spending in R&D, jumped ahead of West German companies, who would otherwise have been second to the U.S. West German companies increased their share of new products to 16% from 13%, but Japan jumped from 10% to 22%. France, which had been in second place during the period 1961–77, was particularly beset by extremely tight price controls levied by the French government, and the resulting poor margins eroded its ability to fund new-drug research.

All those new drugs, or new chemical entities, make up a large, often cluttered category. What is more important is the number of those new drugs that become "important," with world sales of more than $20 million, and "leading," those with world sales of more than $100 million.

The British, usually attacked for having fine research but poor marketing, have actually been the most successful country in converting a new drug into an important market—nearly one in three. Redwood attributes this success to good science, a sound approach to selecting new chemical entities, strong developmental capacity, and determination to market globally.

On the other hand, Swiss, West German, and French companies all lost ground in the ranking order of "important" and "leading" products, because they were not strong in antibiotics, one of the top three classes of pharmaceuticals. Antibiotic discoveries and developments were, rather, one of the strong points of the U.S., British, and Japanese pharmaceutical industries.

C&EN staff photo

Redwood: balance of power changing

So far, the Japanese industry remains rather low on the list of countries introducing "important" or "leading" drugs. But, because of the country's strong performance in introducing new drugs, it "would be very surprising" if Japan did not achieve second position in the categories of "important" and possibly "leading" by the 1990s, Redwood predicts. That will be how long it will take the new drugs of the early 1980s to work their way into significant markets around the world.

Where the new, improved drugs first come to market is probably not crucial, given the global character of the business. However, there are significant differences, continuing for the next few years, in where U.S. and European pharmaceutical companies, and Japanese companies, decide to market and conduct R&D.

To a much greater extent, the study points out, U.S. and European companies have elected to become "multinational"—that is, siting major facilities in other countries. The typical pattern: U.S. companies into Europe; companies in European Community countries into other

EC countries; and, less frequently until recently, European companies into the U.S.

And marketing has, of course, gone international. It is the prime means of global penetration by multinationals, says Redwood. Secondhand marketing, through licensees or distributors, can be very successful and may be the only way in which small companies can exploit their product discoveries in large markets such as the U.S. and Japan, he says. But experience throughout the pharmaceutical industry seems to uphold the view that secondhand marketing is second best.

Although Japanese pharmaceutical companies had set up numerous overseas subsidiaries in Asia and Latin America by the mid-1970s, and some in Europe and the U.S. since then, he says, most of these are generally confined to overseeing imports of pharmaceuticals produced in Japan, in technical liaison with local research-based companies. It has only been in this decade, the study says, that Japanese producers have been willing to enter joint ventures with local firms to take Japanese research discoveries through the regulatory phase and, in some cases, into production. And they have begun buying minority stakes in a few foreign pharmaceutical firms.

Multinationals have been exceedingly cautious about investing in Third World countries, because of what they believe are government policies often hostile to the pharmaceutical industry.

Japan leaps into second place as source for new drugs

Nationality of parent company	Number of new chemical entities introduced 1981–85	% of total 1981–85	% of total 1981–77
U.S.	69	25%	24%
Japan	61	22	10
West Germany	45	16	13
Switzerland	23	8	8
Italy	20	7	7
France	19	7	20
U.K.	12	4	5
Scandinavia	7	2	[illegible]
Others	24	9	[illegible]0
TOTAL	280	100%	[illegible]00%

Source: Heinz Redwood

Although the Third World takes about 15% of the pharmaceuticals produced in developed countries, multinationals supply about 70% of the Third World's pharmaceuticals. Given that kind of imbalance, the study points out, there are some unpalatable lessons that Third World countries must accept. Although what such countries need are technology and expertise, multinational companies seek profit, and their need to seek it in the Third World is less intensive as long as developed countries remain the focal point of their profitability. The threats to pull out production or investment, if conditions in individual developing countries become too tough, are not idle, the study says. To a large multinational corporation, the market in any individual Third World country is "dispensable," and the Third World is not a politically cohesive bloc capable of concerted retaliation.

Multinationals, Redwood says, "can be cajoled, maneuvered, and shamed into many concessions. They will suffer price controls and freezes, high taxation, the uncertainty of capital repatriation, discrimination in favor of local national companies, ownership restrictions, and other hostile financial and legislative measures, always hoping that 'things will change for the better eventually.' But they will not accept piracy or the forcible transfer of their industrial property." They fear committing core technology to a country that might attempt to wrest it from them while it is still unique. And that, more than anything else, he believes, explains their reluctance to produce intermediates or active ingredients in the Third World, although they are increasingly undertaking such critical production in other developed countries.

Wherever the companies are located, however, the same trends of concentration and lessening opportunity for the second- and third-tier pharmaceutical manufacturers are occurring. Increasingly, just as with the chemical industry, size is the essential requirement.

What Redwood predicts may begin to happen is that large companies with small pharmaceutical segments may well decide to sell what are highly marketable "properties," if the industrial climate continues to favor concentration. Diversified companies with major drug operations, or primarily pharmaceutical companies, on the other hand, will prefer to shed their nonpharmaceutical operations. Even among the leading pharmaceutical companies, however, those that fail to perform effectively and innovatively will lose their independence: Some quite large companies will fall by the wayside.

No giant predators have attempted to enter the pharmaceutical business except through acquisition, because the barriers to entry have been too high, in part professional and in part national. Professionally, the R&D "threshold" and the time span from discovery to breakeven on cash flow are "daunting deterrents." Territorially, national markets differ radically from one another, so that local expertise in every aspect of development and marketing is essential. Even inside the drug industry, latecomers who are not yet established in the leading countries of Europe, or in the U.S. or Japan, mostly must enter them by acquisition; starting from scratch would simply be too slow and risky.

That is true even of novel technologies, such as biotechnology, which sees great promise in the pharmaceutical industry. No one can guarantee, of course, that biotechnology will have changed the face of medicine by the end of the century, as antibiotics did in midcentury, but there must be a chance that it will do just that, the study observes. In terms of scientific advance, and of new products that cannot be produced economically by chemical synthesis or traditional fermentation, the eventual impact could be immense. However, there are already signs that many of the new biotech ventures will never see the light of day as independent profitable commercial firms. Some will fold, some will be taken over by pharmaceutical firms for their scientific expertise, and some will be very successful—which will make them still more attractive to predators. □